Power electronic capacitors for low power (PEC LP MKP)

TDK Electronics AG
Aluminum & Film Capacitors Business Group
Munich, Germany
November 2023
# Aluminum & Film Capacitors Business Group at a glance

## Key data

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>Headquarters</td>
<td>Munich, Germany</td>
</tr>
<tr>
<td>Number of plants</td>
<td>8</td>
</tr>
<tr>
<td>Employees total</td>
<td>6600</td>
</tr>
<tr>
<td>Management</td>
<td></td>
</tr>
<tr>
<td>Karl Stoll</td>
<td>CEO</td>
</tr>
<tr>
<td>Bernhard Koch</td>
<td>Deputy General Manager</td>
</tr>
<tr>
<td>Auxi Fernandez</td>
<td>CFO</td>
</tr>
</tbody>
</table>

## Portfolio

### Aluminum electrolytic capacitors
- Screw terminals
- Snap-in / Multi pin / Large size
- Axial-lead / Soldering star
- Single-ended
- Hybrid polymer aluminum electrolytic capacitors
  - SMD
  - Axial-lead / Soldering star

### Film capacitors for Industrial and for Automotive
- DC capacitors
- AC capacitors
- Power capacitor chips for low power (PCC LP)

### Film capacitors for Energy Solutions
- Power electronic capacitors for high power (PEC HP)
- Power factor correction (PFC) capacitors and key components for low and medium voltage (LV, MV)
- Power quality solutions (PQS)
Our Aluminum & Film Capacitors Business Group has a global manufacturing presence.
Plant in Zhuhai, China

Product range

Aluminum & Film Capacitors BG
- Film capacitors
  - DC capacitors
  - Power capacitor chips for low power (PCC LP)
  - **Power electronic capacitors for low power (PEC LP MKP)**
  - Power factor correction (PFC) capacitors and key components for low voltage (LV)
  - Power quality solutions (PQS)

Piezo & Protection Devices BG
- Disk, Energy, Strap and Block varistors
- SMD disc varistors (CU)
- Inrush current limiters (ICLs)
- PTC thermistors

Certification
- ISO 9001
- ISO 14001
- ISO 45001
- IATF 16949

- 85,000 m²
- Founded in 1998
Plant in Gravataí, Brazil

Product range

Aluminum & Film Capacitors BG
- Aluminum electrolytic capacitors
  - Axial-lead/Soldering star
  - Single-ended
  - Screw terminals
  - Snap-in/Multi pin
- Hybrid polymer aluminum electrolytic capacitors
  - SMD

Film capacitors
- DC capacitors
- AC capacitors
- Power factor correction (PFC) capacitors and key components for low voltage (LV)
- Power electronic capacitors for defibrillators (MKP)

Certification
- ISO 9001
- ISO 14001
- ISO 45001
- IATF 16949

43,000 m²
Founded in 1954
PEC MKP capacitors portfolio

MKP AC / MKD AC

Input / Output filter

MKP DC

DC link

Defibrillator

Defibrillator
Power electronic capacitors for low power (PEC LP MKP)

Power capacitors for a wide range of applications

- Solar inverters
- Wind power plants
- Drives
- Traction
- UPS
- EV chargers
- Hydrogen

Solar
Wind power plants
Drives
Traction
UPS
EV chargers
Hydrogen
Defibrillator capacitors for medical applications

**Features**
- Capacitance range 30 to 200 µF, voltage up to 5 kV
- Cylindrical and oval design (plastic or metal case)
- Terminals cable design upon request (straight/flag fast-on & stripped)
- Temperatures up to 60 °C hotspot

**Applications**
- AED (Automated External Defibrillator) and MED (Manual External Defibrillator)

**Benefits**
- Self-healing properties
- Low leakage current; high charge and discharge pulse capability
- Life expectancy up to 10,000 cycles
AC filter capacitors for industrial applications 1/2

Series B32361* & B32362*

Standard solution
- 1-phase
- 20 to 600 μF
- 250 to 480 V_{RMS}

Series B3237X*E/F

Improved resin filled design (portfolio extension)
- 1 & 3 Ph
- 5 to 600 μF
- 250 to 1000 V_{RMS}
- Metal cover
- Tightly sealed

Series B3237*G

New gas filled design – robust series for high requirements
- 1 & 3Ph
- 5 to 600 μF
- 250 to 1000 V_{RMS}
- Metal cover
- Long lifetime
AC filter capacitors for industrial applications 2/2

**Features**
- Capacitance range 20 to 600 µF, 250 to 480 V\(_{\text{RMS}}\)
- IEC 61071-, GB/T17702- and UL 810- compliant
- Temperatures up to 85 °C hotspot
- Single-phase (1 Ph) capacitors

**Applications**
- Capacitors for AC input/output filtering for industrial applications, converters, UPS, drives and wind/solar inverters

**Benefits**
- Self-healing properties
- Overpressure disconnector (tear-off fuse)
MKD AC filter capacitors product range

<table>
<thead>
<tr>
<th></th>
<th>Rated AC $V_{RMS}$ [V]</th>
<th>$C_R$ [µF]</th>
<th>Diameter [mm]</th>
<th>Height [mm]</th>
<th>Others</th>
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<tbody>
<tr>
<td><strong>Single phase</strong></td>
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<tr>
<td>600</td>
<td>5</td>
<td>50</td>
<td>64.5</td>
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<td>B3237* series</td>
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<td>Overpressure disconnector</td>
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<tr>
<td>1000</td>
<td>600</td>
<td>136</td>
<td>245</td>
<td></td>
<td>Available with fast-on terminals, screw terminals (M6 and M10) and clamp terminals</td>
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<tr>
<td><strong>Three phase</strong></td>
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<tr>
<td>250</td>
<td>3 x 5</td>
<td>50</td>
<td>163</td>
<td></td>
<td>Delta connection: B32375* series (fast on terminal), B32376* series (screw terminal), B32377* series (clamp on terminal)</td>
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<td>Star connection: B32378* series (only in the market)</td>
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<tr>
<td>1000</td>
<td>3 x 600</td>
<td>136</td>
<td>350</td>
<td></td>
<td>Overpressure disconnector</td>
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</table>

**Series**
- B32370*
- B32371*
- B32373*
- B32374*
- B32375*
- B32376*
- B32377*
- B32378*
DC-link filter capacitors for industrial applications

**Features**
- Capacitance range 40 4000 µF, 500 to 3000 V DC
- Low ESR <1 mΩ & low ESL <12 nH (B2563*E series, ultra low ESL design)
- Temperatures up to 105 °C hotspot
- IEC 61071, RoHS-compliant and UL 810-compliant

**Applications**
- DC link for renewable energy inverters, industrial drives, e-mobility, medical and traction

**Benefits**
- Tightly sealed (metal top B2568* series)
- Self-healing properties
- 85 °C/85% RH $V_N$ 1000 h (metal top B2568*/resin top B2569* series)
- Life expectancy up to 100,000 hours at hot spot temperature +75 °C
MKP DC filter capacitors product range

<table>
<thead>
<tr>
<th></th>
<th>Rated DC VR DC [V]</th>
<th>$C_R$ [µF] tol. +/- 10%</th>
<th>Diameter [mm]</th>
<th>Height $H_C$ [mm]</th>
<th>Features</th>
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<tr>
<td><strong>Standard</strong></td>
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<td>700</td>
<td>40</td>
<td>85</td>
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<tr>
<td>3000</td>
<td>4000</td>
<td>116</td>
<td>345</td>
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<td><strong>Low LSI, ULSI HF</strong></td>
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<tr>
<td>500</td>
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<td>2000</td>
<td>400</td>
<td>85</td>
<td>65</td>
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<tr>
<td><strong>Heavy duty</strong></td>
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<tr>
<td>900</td>
<td>60</td>
<td>85</td>
<td>99</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3000</td>
<td>4000</td>
<td>136</td>
<td>368</td>
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<td></td>
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<tr>
<td><strong>High PD</strong></td>
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<tr>
<td>700</td>
<td>45</td>
<td>75</td>
<td>95</td>
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<tr>
<td>3000</td>
<td>5500</td>
<td>136</td>
<td>370</td>
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</tr>
</tbody>
</table>

**B2562* series**
- DC link for renewable energies, industrial drives and traction

**B2563* series**
- Ls <13 nH
- DC link for e-mobility

**B2568* series**
- Metal top, tightly sealed
- LS<14 nH with 4T

**B2569* series**
- Resin top, high humidity resistance and partial discharge

**B2568* series features**
- Tightly sealed for operations in harsh environment
- Fire and smoke classification according to EN 45545
- Ultra low ESL (4 terminals upon request)
- Customized designs (high frequency and segmented film) upon request

**B2569* series features**
- Resin top with improved partial discharge capabilities
- High humidity resistance 1.3 $V_N$, 85 °C/85%/500 hours
- Improved high partial discharge (PD) extinction voltage >1.6 kV AC (10 pC)
Power capacitors in round can for DC applications applications

MKP DC standard
B2562/B2569

MKP DC HF (EVO design)
B2568

MKP DC Metal top
B2569

MKP DC 4T
B25695

MKP DC HT 105 °C
B2563*E

MKP DC ULSI

- **40 µF**
- **5500 µF**
- **700 V DC**
- **3 kV DC**

MKP DC standard

- **40 µF**
- **4000 µF**
- **700 V DC**
- **3 kV DC**

High frequency Si and SiC designs
20% lower ESL 10% lower ESR than standard

MKP DC HF (EVO design)

- **80 µF**
- **3000 µF**
- **900 V DC**
- **3 kV DC**

Tight Sealed
Specially for traction applications

MKP DC Metal top

- **40 µF**
- **4000 µF**
- **900 V DC**
- **3 kV DC**

Special types
Very low ESL <10 nH
65% lower ESL than standard
Hermetically sealed

MKP DC 4T

- **40 µF**
- **4000 µF**
- **900 V DC**
- **2 kV DC**

Very low ESL <12 nH
High frequency design
Ready for SiC

MKP DC HT 105 °C

- **40 µF**
- **270 µF**
- **700 V DC**
- **2 kV DC**

MKP DC ULSI

- **20 µF**
- **2 kV DC**

High frequency Si and SiC designs

MKP DC ULSI

- **2 kV DC**

New

Power electronic capacitors for low power (PEC LP MKP)
Available sizes

**MKP DC LSI/ULSI**
- D 85 mm
- H 50,65 mm
- C: from 20 µF to 270 µF
  - V: from 700 V to 2 kV

**2T MKP DC**
- D: 75, 85, 90, 100, 116, 136 mm
- H is flexible
- C: from 40 µF to 6 mF
  - V: from 700 V to 3 kV

**4T MKP DC**
- D: 116 mm
- H is flexible
- C: from 40 µF to 4 mF
  - V: from 700 V to 3 kV

- 6 diameters available for all MKP DC
- D 85,100 and 116 mm are the high runners
- Big flexibility in height due to big range of film width
- 1, 2 or 3 windings inside depending on the specification needed to be achieve
- Standard film widths 50 mm, 62.5 mm, 75 mm, 100 mm
- D 85 mm available for ULSI/LSI
- Example of design of 2 windings
Recommendations for EV charging

High-power density

- Trend to develop high-power density converters using SiC semiconductors
- Capacitors with high current capability, ultra low ESL and lower ESR at high frequencies are requested
MKP DC ultra low inductance (ULSI)
Series B2563*E ultra low ESL <13 nH

Main applications
- DC fast charging
- Solar string inverters
- Induction heating
- Traction
- High-speed switching applications

Product description
- Capacitance range 20 to 270 µF; V DC: 700 V to 2 KV
- ESL <13 nH
- Low ESR over frequency
- Diameter: 85 mm
- Height: 50 and 65 mm
- Male (M8) or female (M5) terminals
- High current capability
- DC link for SiC power modules and Si modules with high-speed switching
- For 85 °C HS, (samples available at higher temperatures)
MKP DC ULSI HF
ESR versus frequency

Typical switching frequency power module
20 kHz to 40 kHz, so it is important to characterize the capacitor to low/stable ESR values until several hundreds kHz and consider all the harmonics for the thermal considerations

110 µF, 1000 V DC
10 kHz: 1.18 mΩ
100 kHz: 1.38 mΩ
160 kHz: 1.5 mΩ

Low ESR in the working frequency range
MKP DC metal top series B2568*

Tightly sealed MKP DC series with metal top disk (B2568*)

- **Range:** 900 V to 3 kV, 50 µF to 4 mF
- **Main DC link voltage for traction:** 1 kV for 1.7 kV IGBTs and 2 kV for 3.3 kV IGBTs
- **Target applications**
  - Traction inverters
  - Commercial agricultural vehicles (CAV)
  - Medium-voltage drives (MVD)
- **Humidity:** 85 °C/85% RH 1000 hours
- **Fire & smoke classification acc. to EN 45545:** R22: HL3 R23,; HL2
- **Dimensions:** Ø 85, Ø 116 and Ø 136 mm; height 74 mm to 368 mm
- **Light weight** (aluminum)
- **Good cooling** (normally stacked 2 windings)
- **Ultra low ESL with 4 terminals (4T) design** (<14 nH, in some cases <10 nH possible)

Standard datasheet available under 
www.tdk-electronics.tdk.com/en/power_capacitors

For harsh operating conditions especially traction applications
Tightly sealed MKP DC series with 4 terminals (4T) for ESL <14 nH (B25689* series)

- **Range:** 900 V to 3 kV, 50 µF to 3 mF
- **Main DC link voltage for traction:** 1 kV for 1.7 kV IGBTs and 2 kV for 3.3 kV IGBTs
- **Target applications**
  - Traction inverters
  - All high-speed switching applications
- **Humidity:** 85 °C/85% RH 1000 hours
- **Fire & smoke classification acc. to EN 45545:** R22: HL3 R23: HL2
- **Dimensions:** Ø116; height: 74 to 345 mm
- **Light weight** (aluminum)
- Good cooling (normally stacked 2 windings)
- Approx. **60% less ESL** than standard capacitor with 2T
- Typical ESL 12 to 15 nH (special designs with 10 nH possible)
- Lifetime up to 200,000 hours
- Samples available

**MKP DC metal top series B2568***

Modular approach comparison 2T vs 4T

Typical values requested – diameter = 116 mm

<table>
<thead>
<tr>
<th>Hc (mm)</th>
<th>1000 V DC (1.7 kV power modules)</th>
<th>1800 V DC (3.3 kV power modules)</th>
<th>2000 V DC (3.3 kV power modules)</th>
<th>ESL 2 terminals</th>
<th>ESL 4 terminals</th>
</tr>
</thead>
<tbody>
<tr>
<td>75</td>
<td>360 µF</td>
<td>100 µF</td>
<td>80 µF</td>
<td>32</td>
<td>13</td>
</tr>
<tr>
<td>100</td>
<td>550 µF</td>
<td>165 µF</td>
<td>130 µF</td>
<td>25</td>
<td>10</td>
</tr>
<tr>
<td>179</td>
<td>1100 µF</td>
<td>330 µF</td>
<td>260 µF</td>
<td>34</td>
<td>14</td>
</tr>
<tr>
<td>229</td>
<td>1500 µF</td>
<td>450 µF</td>
<td>360 µF</td>
<td>38</td>
<td>15</td>
</tr>
</tbody>
</table>

Typical values requested – diameter = 85 mm:

<table>
<thead>
<tr>
<th>Hc (mm)</th>
<th>1000 V DC (1.7 kV power modules)</th>
<th>1800 V DC (3.3 kV power modules)</th>
<th>2000 V DC (3.3 kV power modules)</th>
<th>ESL (typical nH)</th>
</tr>
</thead>
<tbody>
<tr>
<td>179</td>
<td>550 µF</td>
<td>160 µF</td>
<td>130 µF</td>
<td>22 nH</td>
</tr>
<tr>
<td>229</td>
<td>740 µF</td>
<td>220 µF</td>
<td>180 µF</td>
<td>25 nH</td>
</tr>
<tr>
<td>252</td>
<td>810 µF</td>
<td>240 µF</td>
<td>195 µF</td>
<td>28 nH</td>
</tr>
</tbody>
</table>

*Special types with even lower ESL upon request*
MKP DC HF EVO: The DC link for the next generation power converters

- **Lower ESL** than standard MKP DC (around 20% lower)
- **Lower ESR** compared with standard MKP DC (around 5 to 10% lower)
- Overlapped busbars for **homogeneous current distribution**
- **Internal resonances avoided**
- To be used in combination with SiC or when there is a considerable current at high frequencies
- In final approval stage; series from September 2023
- Datasheet available end of Q2/2023; samples from June 2023
- Applications: Solar & wind inverters, industrial drives, traction aux. inverters

NEW
MKP DC 105 °C series B25695*
Improving the DC link performance

- Datasheet available in April 2024
- Diameters 85, 116 mm; voltages from 900 V to 1.6 kV
- Lifetime will be specified for 95 °C and 105 °C HS
- Design-in upon request, samples available
- Epoxy resin instead of PU, improved process
- Applications: Solar & wind inverters, industrial drives, traction inverters
MKP DC 105°C series B25695*

Series advantages

- Higher current capability (higher self-heating allowed)
- Higher ambient temperature possible (e.g. less cooling)
- Hot spot allowed till 105 °C (derating to be considered)
- Solution could be done more compact
MKP-DC battery – CFD simulations
Overview & boundary conditions

- We offer CFD simulations to customers
- Depending e.g. on distance between capacitors and velocity of air we can change self-heating of the capacitor

**General data**
- P/N: B25620B0757K881
- Capacitance: 6.75 mF
- Voltage: 900 VDC
- $I_{\text{total}}$: 600 A\(_{\text{RMS}}\)

**Common boundary conditions**
- Ambient temperature: 70 °C
- Losses: 7 W/capacitor
- Busbar losses: 16 W
- Air direction: from right to left
- Active cooling temperature (when present): 65 °C
MKP-DC battery – CFD simulations
Forced convection

Specific boundary conditions
- Air velocity: 1.5 m/s
- Separation between capacitors: 10 mm
- No active cooling considered

Results (hotspot temperatures)
- First row: 85.2 °C → -12.9 K
- Second row: 89 °C → -18.4 K
- Third row: 92 °C → -21.9 K
Recommendations for renewable energies
Solar & wind applications

Better efficiency

- **Solar** Since PV is strongly influenced by cost pressure then new inverters are forced to offer very high efficiency (97 to 98%) with longer maintenance periods.

- Application is demanding cost-optimized standard products with higher nominal voltages and reduced ESR/ESL Capacitors should be optimized to work at higher frequencies

- **Wind** is as well strongly influenced by cost pressure with a trend to increase the output power specially in off-shore applications

- Both applications are demanding higher current densities
Recommendations for traction applications

High power density

- In light train applications, the use of light and low volume converters is a must, so standardization of components (modular platforms) together compact designs is highly appreciated.

- Becoming more popular the use of fast switching IGBTs and SiC semiconductors with higher switching frequencies. This requires low ESL capacitors; two good series are our MKP 4 terminal capacitors with ESL as low as 10 nH.